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NORMALIZING OF VIBRATIONS IN FIBEROPTICS DRAWING PLANTS

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The effect of vibrations of drawing plants on a deviation in the diameter of the fiber drawn is estimated. An elastic filament is accepted as a calculation model. The boundary conditions include kinematic disturbance caused by vibrations of the drawing mechanism.

The quality of the optical fiber in drawing to a large extent depends on the stability of the technological parameters, of which the most essential is the drawing velocity, which depends on the drawing mechanism. An irregular drawing velocity is primarily caused by variations in the angular velocity of the exit section of the drawing mechanism. However, such nonuniformity may be caused by vibrations of the drawing plant in general and especially of its main unit, i.e., the drawing mechanism directly contacting with fiber.

Apart from this, vibrations are transmitted via fiber directly into the zone of fiber formation and thus may affect the process of fiber formation and, consequently, fiber quality. Such an effect was considered in [1]. Vibrations in that case were normalized primarily based on the amplitude of vibrations of the drawing-mechanism grips.

The purpose of our study is to estimate the effect of vibrations on nonuniformity of the drawing velocity. An estimation model (Fig. 1) was used for this purpose. Fiber *1* is being drawn from a softened intermediate product *2* using the drawing mechanism *3*. Fiber within a segment of length l between the drawing-mechanism grips and the molding zone is modeled by an elastic filament, whose vibrations are calculated using the wave equation [2]:

$$\frac{\partial^2 y}{\partial t^2} = \frac{F}{\rho}\frac{\partial^2 y}{\partial z^2}, \qquad (1)$$

where y is the lateral shift of the filament; t is the time; F is the drawing force developed by the drawing mechanism; ρ is the linear density of the glass; z is the coordinate along the filament axis.

Let us assume similarly to [1] that a kinematic harmonic disturbance exists at the point of contact between the fiber and the drawing mechanism, which is caused by the drawing-mechanism vibrations. Then boundary conditions for Eq. (1) will take the form

$$\begin{cases} y(0, t) = 0; \\ y(l, t) = A \sin \omega t, \end{cases} \qquad (2)$$

where A and ω are, respectively, the amplitude and the frequency of vibrations of the drawing-mechanism grips.

Conditions (2) make it possible to determine the shape of the main vibration of the lateral vibrations of the filament:

$$\varphi(z) = \frac{A}{\sin kl} \sin kz, \qquad (3)$$

where $k = \omega\sqrt{\frac{\rho}{F}}$.

Vibrations of the filament will cause its additional elongation, which will produce variations in the drawing velocity. During a time period

$$t = \frac{T}{2} = \frac{\pi}{\omega} = \frac{1}{2f},$$

where T and f are, respectively, the period and the frequency

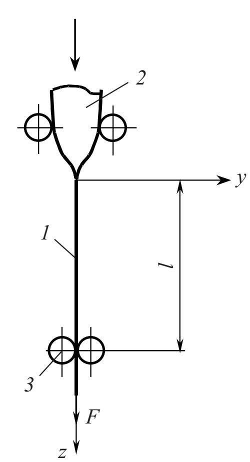

Fig. 1. Fiber-drawing scheme.

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of forced vibrations, the filament will become longer by a value Δl determined by the following expression [3]:

$$\Delta l = \int_0^l \sqrt{1 + (\varphi'(z))^2}\, dz - l, \tag{4}$$

where $\varphi'(z) = \frac{d\varphi}{dz}$.

Since the deflections of the filament are insignificant and $(\varphi'(z))^2 \ll 1$, we can use an approximated equality:

$$\sqrt{1 + (\varphi'(z))^2} \approx 1 + \frac{(\varphi'(z))^2}{2}. \tag{5}$$

By substituting expressions (3) and (5) into formula (4), we will obtain after integrating

$$\Delta l = \frac{(A\pi\alpha)^2}{2l\sin^2\pi l}\left(0.5 + \frac{\sin\pi l}{4\pi l}\right), \tag{6}$$

where $\alpha = \frac{f}{f_1}$ $\left(f_1 = \frac{\pi}{l}\sqrt{\frac{F}{\rho}}\right)$ is the first natural frequency of the lateral vibrations of the filament.

Elongation Δl causes variations of the drawing velocity with an amplitude Δv, which can be related to Δl by means of the relationship $\Delta l = 0.5\Delta vT = 0.5\Delta v/f$.

The nonuniformity of the drawing velocity due to the filament vibrations will be determined in the following way:

$$\mu_v = \frac{\Delta v}{v} = \frac{2\Delta l\alpha f_1}{v}. \tag{7}$$

To relate μ_v with the deviation Δd in the diameter d of the fiber cross section, we will use the dependence

$$D^2 v_f^2 = d^2 v^2,$$

where D is the cross-section diameter of the intermediate product and v_f is the rate of feed of the intermediate product.

We are assuming D = const and v_f = const. Then

$$\frac{\Delta d}{d} = \left|(1 + \mu_v)^{-0.5} - 1\right|. \tag{8}$$

By substituting μ_v based on condition (7) and Δl from formula (6) into expression (8) we will get a dependence

$$\Delta d = \Delta d(\alpha).$$

Thus, the considered relationships make it possible to normalize the drawing-mechanism vibrations not only based on the amplitude of vibrations of the drawing-mechanism grips [1], but also based on the frequency range of vibrations.

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